Δελτίο της Ελληνικής Γεωλογικής Εταιρίας, 2010
Πρακτικά 12ου Διεθνούς Συνεδρίου
Πάτρα, Μάιος 2010

Bulletin of the Geological Society of Greece, 2010
Proceedings of the 12th International Congress
Patras, May, 2010

THE CONTRIBUTION OF MUSEUMS' DIGITALIZED PALAEONTOLOGICAL COLLECTIONS TO THE SCIENTIFIC LITERACY OF COMPULSORY EDUCATION STUDENTS: THE CASE OF AN INTERACTIVE MULTIMEDIA PRODUCTION OF THE PALAEONTOLOGICAL AND GEOLOGICAL MUSEUM OF THE UNIVERSITY OF ATHENS

G. Fermeli[1] and M. Dermitzakis[1]

[1] *Faculty of Geology and Geoenvironment, Dept. of Hist. Geology and Palaeontology, National and Kapodistrian University of Athens, Panepistimiopolis, 15784 Zographou, Athens, Greece, gfermeli@geol.uoa.gr, mdermi@geol.uoa.gr*

Abstract

The aim of the current paper is to present an interactive trilingual multimedia production, which designed in order to support school students' scientific literacy; as well as to enhance them the awareness, provision of information and education mainly in matters of palaeontology. In order to achieve scientific literacy, school students, must interact with scientific objects and data and must experience the role of interpretation and analysis in problem solving activities. The current production, based on a part of the digitized collections of the Palaeontological and Geological Museum of the University of Athens, offers this opportunity to the school students.

The application is a stand-alone learning environment and is divided into two parts. In the first part, there are presented the key geological concepts and the second part comprises interactive educational activities. Through an environment that promoted the development of observation skills, quest for information, decision-making procedures, critical thinking and systematization and following the spiral development of the material, there have been designed two sets of activities: one - for Primary and one - for Secondary education.

***Key words:** geosciences literacy, scientific literacy, museums, digitalized palaeontological collections, education, virtual environment, Greece.*

1. Introduction

The Museum of Palaeontology and Geology of the University of Athens was created in 1835. Nowadays, it still maintains its primary objectives -collection, maintenance and research- while at the same time further developing its newer objectives, namely - exhibition, interpretation and education.

The university museum offers its visitors the possibility of training, study and entertainment on the grounds that the evolution of life on our planet has been imprinted in the geological strata, through different categories of plant and animal fossils.

In the museum, a special emphasis is placed on developing experiential educational activities through which visitors can understand various geological upheavals, climatic as well as environmental changes over the millions years. Based on the project digitization of a part of the Museum's collections, there has been also created a trilingual interactive multimedia production designed in order to enhance the awareness, provision of information and education to the pupils mainly in matters of geosciences.

Within the digitization programme of the museum, there have been digitalized numerous palaeontological samples for scientific and resource purposes. At the same time, one of the aims of the programme is to support the scientific literacy of the school students. For this purpose a production of a digital interactive educational application (DVD) under the title «A journey in time and space», was implemented within the framework of the programme Digitization of the Museums of National and Kapodistrian University of Athens (Fermeli & Dermitzakis, 2008).

2. Theoretical background

2.1 Scientific literacy

The term "scientific literacy" was coined in the late 1950s, and most probably appeared in print for the first time when Paul Hurd (Hurd, 1958) used it in a publication entitled *Science Literacy: Its Meaning for American Schools* (Laugksch, 2000).

In recent years, the term "scientific literacy" has become increasingly prominent in discussions of the aims and purposes of school science education. In the UK, the Beyond 2000 report argued that the purpose of science education, as a component of young people's whole educational experience, is to prepare them for a full and satisfying life in the world of the 21st century. The same report refers to the fact that 'the science curriculum from 5 to 16 should be seen primarily as a course to enhance scientific literacy' and continues saying that the compulsory science curriculum should be designed to develop the scientific literacy of future citizens. It also recommends that from about the age of 14 a separate, parallel course is needed to prepare those young people who opt for it for more advanced study in science (Millar & Osborne, 1998).

However, the term 'scientific literacy" has been used in different contents by many authors. For example, the International Forum on Scientific and Technological Literacy for All offered a variety of views, such as: «The capability to function with understanding and confidence, and at appropriate levels, in ways that bring about empowerment in the made world and in the world of scientific and technological ideas» (UNESCO, 1993).

The US National Science Education Standards defined scientific literacy as, «the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity» (National Research Council-NRC, 1996).

Bybee (1997) has proposed four levels of scientific literacy, from the lowest to the highest as follows: «nominal scientific literacy», «functional literacy» «conceptual and procedural scientific literacy» and «multidimensional scientific literacy».

The third level is the most appropriate for the purposes of the OECD/PISA science framework instead of the forth, which includes understanding of the nature of science and of its history and role in culture, at a level most appropriate for "some students-the scientists of tomorrow" rather than for all citizens.

According to OECD/PISA (2003), scientific literacy is the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity.

The OECD/PISA (2003) definition of scientific literacy comprises three aspects: a) Scientific knowledge or concepts, which will be assessed by application to specific subject matter; b) Scientific processes which, because they are scientific, will involve knowledge of science, although in the assessment this knowledge must not form the major barrier to success; and c) Situations or context in which the knowledge and processes are assessed and which take the form of science-based issues.

These should be the products of science education for all students. For some students, the minority of whim will become the scientists of tomorrow; this will be extended to in-depth study of scientific ideas and to the development of the ability to «do science».

Although these aspects of scientific literacy are discussed separately, it must be recognised that, in the assessment of scientific literacy, there will always be a combination of all three.

International Student Assessment (PISA) programme of Organization for Economic Co-operation and Development (OECD) has assessed the domain of science literacy (as well as reading and mathematical literacy) of 15-year-old students. Surveys conducted worldwide reveal that even adults, who express strong interest and support for science, do not have a firm grasp of basic scientific facts and concepts, nor do they have an understanding of the scientific process. Usually, adults pick up information about Science media (from watching television or print media), however media can be faulted for miscommunicating science to the public by sometimes failing to distinguish between fantasy and reality and by failing to cite scientific evidence when it is needed (NSF, 2004).

2.2 Geosciences literacy

Geosciences literacy constitutes part of scientific literacy. An Earth-science-literate public, informed on current and accurate scientific understanding of Earth, is critical to the promotion of good stewardship, sound policy, and international cooperation. Earth science education is important for individuals of all ages, backgrounds, and nationalities. (ESLI, 2009).

In recent years, several geological communities have been developing "Geosciences literacy frameworks" as enhancements to the National Curriculums. Like curriculum, these new geosciences literacy frameworks have focused on K-12 education, although they are also intended for informal education and general public audiences. These geosciences literacy frameworks potentially provide a more integrated and less abstract approach to science literacy that may be more suitable for non-science major students that are not pursuing careers in science research or education (Fig.1). They provide a natural link to contemporary environmental issues - e.g., climate change, resource depletion, species and habitat loss, natural hazards, pollution, development of renewable energy, material recycling (ESLI, 2009).

2.3 Geosciences Education in Greece

In Greece, as from 1997, geology has not existed as an independent discipline in higher secondary education (Lyceum). Some geological issues are included in two optional subjects ("Issues of Environmental studies" and "Natural resources management") in the 2nd Grade of Lyceum, however a short percentage of students select these optional subjects. In respect of compulsory education, geology has a better perspective. In lower High School (Gymnasium), there exists a subject "Geology-Geography" in the 1st and 2nd grades, taught for 2 hours per week. In primary school, Geology (as well as Physics, Chemistry, Biology and Geography) is included in the subject "Environment's Study" for 1^{st}, 2^{nd}, 3^{rd} and 4^{th} Grades and "Study the natural world" in the 5^{th} and 6^{th} Grades (Fermeli & Marcopoulou-Diacantoni, 2004).

Following the analysis of the above mentioned text books, it arises that the presence of geology is limited. However, if we agree that geosciences literacy is necessary/important then we have to design specific programmes to foster the interest in geosciences among young people, by developing students' interests outside the classroom.

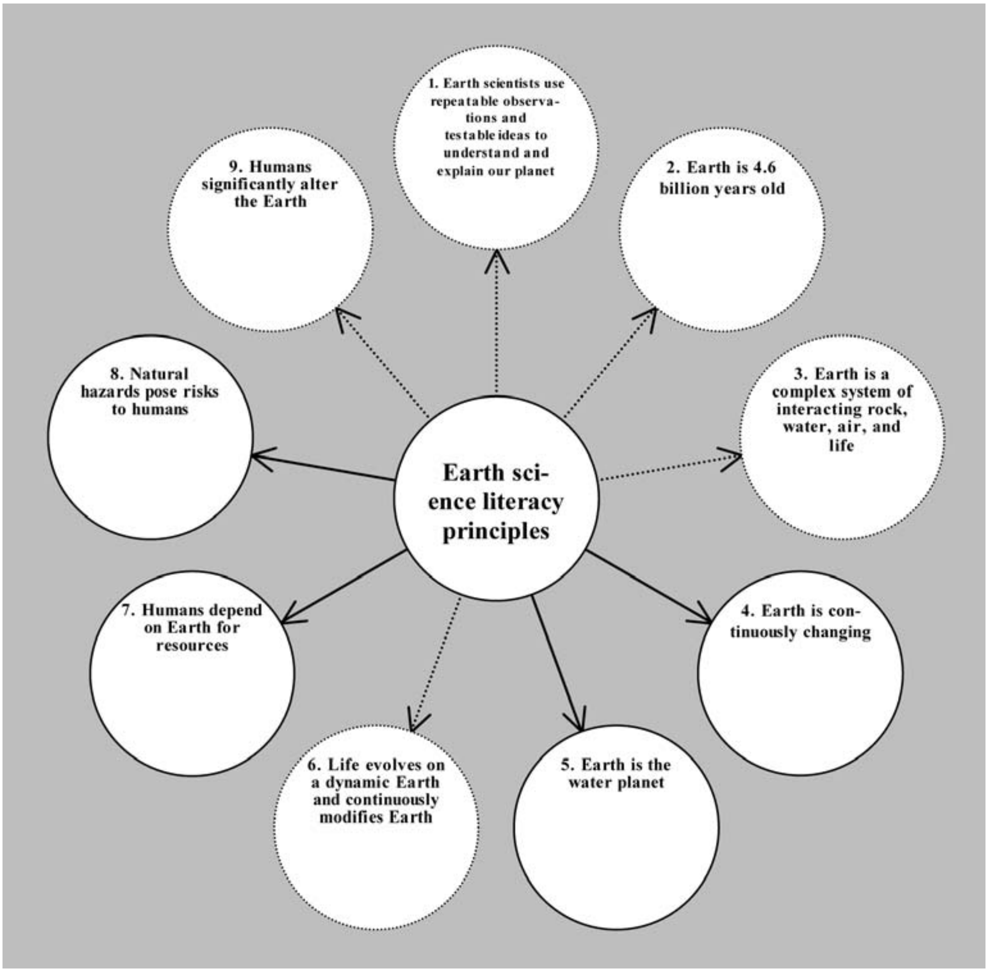


Fig. 1: Overview diagram of Earth Sciences Literacy principles (ESLI, 2009).

Students' geoscientific literacy is not an exclusive target of school education; therefore museums can play an important role in this process - both in formal and informal education. Griffin (1998) mentions that museums provide to us the opportunity to explore using our hands and our minds in numerous and varied ways. They also provide unique opportunities to closely examine specimens (or objects), to understand detail and also allow appreciation of the big picture by providing a wide range of specimens or objects to allow comparisons. In museums, students can develop perceptual skills that teach them how to gather information from "objects" and experiences. Henriksen & Froyland (2000) referred to the possible contribution of museums to scientific literacy and argue that in the present situation, it is no longer enough for museums to contribute to the cultural and professional/economic aspects of scientific literacy. Innovative ways of using the museums' collections and expertise need to be conceived to realize museums' potential to contribute also to the civic and practical aspects of scientific literacy.

MacDonald & Alsford (1997) point out that digital technologies offer a large scale of possibilities for the dissemination of knowledge, thus transforming museums: "In addition to the physical dimension of material objects, this transformation will give the museum another dimension, a digital one. This digital dimension will lead to a new form of museum that enriches the objects with information: the meta-museum which consists of a physical museum and a digital dimension".

University museums, even small local geological and palaeontological museums or collections of natural history which display a limited number of objects in exhibits could foster the interest in local societies particularly among the young people. On the other hand, digitalized palaeontological museums collections offer opportunities to use new media that appeal to the senses, stimulate the imagination, relate science to everyday life, and allow visitors to discover geosciences in ways that are both accessible and interesting to many different categories of visitors. Such digital educational applications are most effective when they draw on the expertise of both researchers and educators and implicate both continual and mutual process of education.

Geosciences community has the objects (real and/or digital) and a clear aim (contribution to the scientific literacy of school students); it has to find attractive ways to express in words learning opportunities that can be understood by all. The objects, like fossils, are an effective means of helping to dissipate misconceptions of geosciences as boring, irrelevant or too difficult.

3. Digital application: "Journey in Time and Space"

3.1 Design and development of the application

The Geological and Palaeontological museum of the University of Athens, based on the project digitization of a part of the Museum's collections, has created a trilingual interactive multimedia production designed in order to enhance the awareness, provision of information and education to the school students mainly in matters of palaeontology.

The aim for this production under the title: "Journey in Time and Space" was to use a number of the digitalized palaeontological samples of the palaeontological museum of the University of Athens in order to support: a) the scientific literacy of students (of compulsory education) and b) encourage cross thematic educational procedure in schools.

In order to achieve the above mentioned aim, there has been a prototype compulsory school geosciences curriculum unit, based on the national curriculum (YPEPTH, 2003a & YPEPTH 2003b) as well as mainly on geosciences literacy framework (ESLI, 2009). Two cross thematic concepts ("Time" and "Space") have been chosen and finally, there have been designed and developed in both of them (curriculum unit and cross thematic concepts) a number of digital interactive educational activities under the general title "Journey in time and space" (Table 1). Each activity consists of a multi-user virtual environment with virtual contexts and digital fossil samples that directly and implicitly guide learner investigations. All materials, within the virtual environment, are presented in three languages (Greek, English and French).

Digital interactive educational applications based on museums digitalized collections offers school students, as well as informal education and general public audiences, opportunities to "drill down" to greater levels of detail, according to their interests or information needs. Introducing digital (or on line) resources – including visualizations of data sets, simulations and interactive games –helps school students develop skills in assessing the kinds of science-oriented material they will see after they leave high school – hence maintaining and enhancing their science literacy.

Table 1.

Part of Geosciences literacy framework on which the application "Journey in time and space" (ESLI, 2009) is based	**Units of the application "Journey in time and space"**
Earth scientists use repeatable observations and testable ideas to understand and explain our planet ***Earth science investigations take many different forms***. *Earth scientists do reproducible experiments and collect multiple lines of evidence. This evidence is taken from field, analytical, theoretical, experimental, and modelling studies.* ***Earth scientists use their understanding of the past to forecast Earth's future***. *Earth science research tells us how Earth functioned in the past under conditions not seen today and how conditions are likely to change in the future.*	– What is palaeontology – The work of a palaeontologist – A day of a palaeontologist in the field – Palaeontological excavation – The history of the museum
Earth is 4.6 billion years old ***Life on Earth*** *began more than 3.5 billion years ago (Fossils indicate that life began with single –celled organisma, which were the only life forms for billions of years. Humans (Homo sapiens) have existed for only a very small fraction (about 0.004%) of earth's history.*	– Geological Time-Virtual visit in the museum – The age of the Earth – Put the time of the Earth in the geological time table – Geographical distribution of fossils- Virtual visit in the museum – A different treasure
Earth is a complex system of interacting rock, water, air, and life ***Earth's climate*** *is an example of how complex interactions among systems can result in relatively sudden and significant changes. The geologic records show that interactions among tectonic events, solar inputs, planetary orbits, ocean circulation, volcanic activity, glaciers, vegetation, and human activities can cause appreciable, and in some cases rapid, changes to global and regional patterns of temperature and precipitation.*	– The climate is changing in Attica region
Life evolves on a dynamic Earth and continuously modifies Earth ***Fossils are the preserved evidence of ancient life***. *Fossils document the presence of life early in Earth's history and the subsequent evolution of life over billions of years.* ***Evolution, including the origination and extinction of species, is a natural and ongoing process***. *Changes to Earth and its ecosystems determine which individuals, populations, and species survive. As an outcome of dynamic Earth processes, life has adapted through evolution to new, diverse, and ever-changing niches.* ***Biological diversity, both past and present, is vast and largely undiscovered***. *New species of living and fossil organisms are continually found and identified. All of this diversity is interrelated through evolution.*	– Fossils -Fossilization – My own palaeontological diary – Who is who – Palaeo- puzzle – The climate is changing in Attica region (2) – Group of fossils – Characteristic exhibits – The museum collections – An interview of the Maastricht monster

(continued)

Table 1 (continued)

Part of Geosciences literacy framework on which the application "Journey in time and space" (ESLI, 2009) is based	Units of the application "Journey in time and space"
More complex life forms and ecosystems have arisen over the course of Earth's history. *This complexity has emerged in association with adaptations to new and constantly changing habitats. But not all evolution causes greater complexity; organisms adapting to changing local environments may also become simpler.* ***Mass extinctions occur when global conditions change faster than species in large numbers can adapt****. Mass extinctions are often followed by the origination of many new species over millions of years as surviving species evolve and fill vacated niches.* ***The particular life forms that exist today, including humans, are a unique result of the history of Earth's systems****. Had this history been even slightly different, modern life forms might be entirely different and humans might never have evolved.* ***Life changes the physical and chemical properties of Earth's geosphere, hydrosphere, and atmosphere.*** *Living organisms produced most of the oxygen in the atmosphere through photosynthesis and provided the substance of fossil fuels and many sedimentary rocks. The fossil record provides a means for understanding the history of these changes.*	– A geological scale – The history of the earth through fossils – Paint your own palaeontological stamp – Palaeo-quiz 1, 2

3.2 Description of the application

The application is divided into two "microcosmos" -The museum of Palaeontology and Geology and the Museum of Archaeology and History of Art- which are connected and interact mainly through the cross thematic significances "Time" and "Space".

This application is a stand-alone learning environment which drives students to learn following their personal interest and curiosity. This way, school students are gaining more than simple knowledge; they are practising scientific investigative processes. The application is also designed for use in a classroom context, supplemented by conventional classroom activities such as textbooks and teacher-led discussions.

In this paper, only the "microcosmos" of the Museum of Palaeontology and Geology is presented. This "microcosmos" is divided into two main parts. In the first part, there are presented the key geological concepts, such as geological time, types of rocks, the process of fossilization, fossils etc as well as a part of the exhibits and digitized collections of the museum. The aforementioned part can constitute: i) Educational support materials for teachers in order to: i) teach the concepts presented by the DVD and included in the school curriculum (Geology, Environmental Studies, etc.), ii) support educational activities in the context of the Environmental Education or iii) prepare students for a visit to the Museum. ii) Material for the pupils' self-study.

The second part comprises interactive educational activities that rely on basic general concepts and the museum's collections that have been presented in the first part of the application. Through an environment that promoted the development of observation skills, quest for information, decision-making procedures, critical thinking and systematization and following the spiral development of the material, there have been designed two sets of activities: one - for Primary and one - for Secondary education.

Fig. 2: "Journey in Time and Space": Virtual visit to the Museum of Geology and Palaeontology.

Every activity leads to a form of assessment of the user. There is also an evaluation activity as concerning the total of the educational activities for every level of education.

More analytically, the application is divided into four units: a) Virtual museum's visit, b) Time, c) Play area and d) Museum's identity.

a) Virtual museum's visit: This unit includes 5 subunits (Geological time, geographical distribution, fossils' category, impressive fossils, and Fossils' collections). The visitor can choose the way in which he/she would like to make a virtual visit to the museum (through time, geographical distribution, fossils' categories or to select to see the most representative and impressive fossil samples of the museum) (Fig. 2).

The most interesting part in this unit is the one, comprising the activity based on digitalized palaeontological fossil collections (Fig. 3). This activity is like a "Virtual museum", in which visitors can choose to see fossils from three main collections (vertebrates, invertebrates, plants) or to see fossils according to their age or geographical distribution. For each fossil, there is presented a detailed identity card with all information about it.

b) Time: Geology is the science with the clear focus on deep time and on the procedures of retro diction. It is proposed that collective and individual grasp of deep time influences the quality of engagement with a host of broader matters, ranging from current environmental issues (e.g. sea-level change and coastal retreat) to longer-term matters (e.g. mass extinctions, asteroid impacts, periods of enhanced volcanic activity, evolution of the Universe). It is suggested that, if we have an insecure deep time framework, we will be less able to accommodate new learning of geosciences concepts with a strong (deep) temporal component. As both teachers and learners we will, therefore, tend to avoid such new knowl-

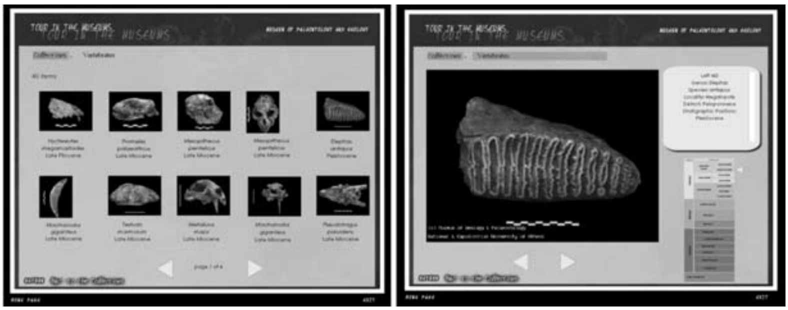
a  b

Fig. 3: (a): Activity based on digitalized palaeontological collections (vertebrates, invertebrates, plants); (b): Fossil's identity card.

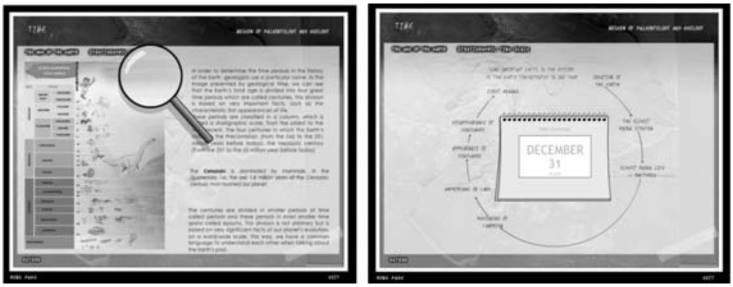


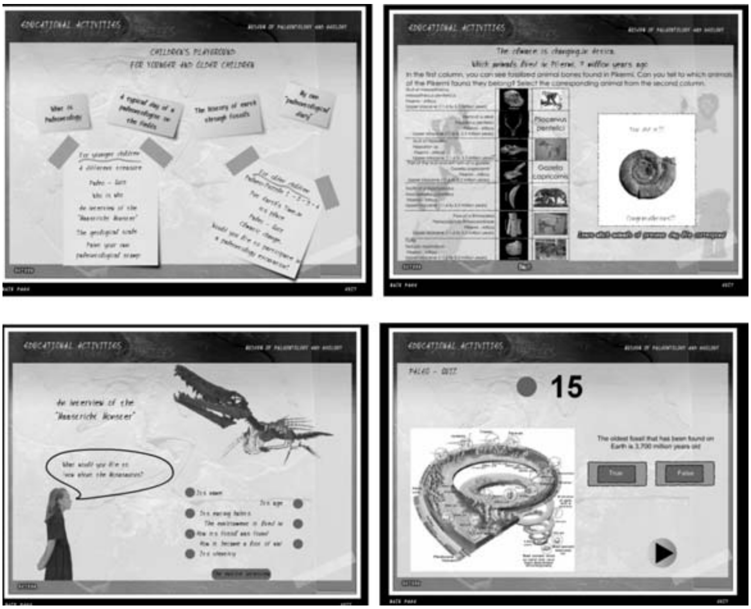
Fig. 4: Time's activities.

edge and understanding (Roger, 2000).

In this unit, there is discussed the concept of geological time. Except the introductory text about geological time, there is also presented information about the age of the Earth and the subsequent evolution of life over billions of years. In addition, there is an interactive activity, following which the school students face the task to order time intervals in the geological time table (Fig. 4).

c) Play area: This unit includes educational activities (General activities, activities for primary school students and activities for secondary school students). Students are familiarized with the proposed activities in experimental work. They cultivate scientific dexterities and problem solving abilities. They can also test their ideas. School students participate in teamwork, develop positive attitudes toward the educational material and are actively involved in the educational process (Fig. 5).

d) Museum's identity: This unit presents the history of the museum of palaeontology and geology of the University of Athens from its creation in 1835 till currently through video, texts and pictures.



a b c d

Fig. 5: (a): Characteristic examples of school students' activities from the Play area unit; (b): Climatic change in Attica region; (c): Interviewing the Maastricht "monster"; (d): Overall evaluation activity.

4. Conclusions

People of all ages better absorb information on any topic, even a very complex one, when they are directly and personally involved. There is no doubt that motivation is the primary factor in increasing interest in geosciences. In seeking to help improve scientific/geosciences literacy, it is therefore necessary to address not only the intelligence but also the imagination and the emotions, in order to make geosciences understandable, as it is only when one has understood that he/she can make a valid contribution to discussions of geosciences.

To achieve scientific literacy, adolescents as well as adults, must interact with scientific objects (real and/or digital) and data and must experience the role of interpretation and analysis in problem solving activities. Through their exhibits and digitalized collections, museums can offer this opportunity to the school students and general public too. However, museums offer a large range of information, which may seem overwhelming to students. Helping students to recognize the way in which this information is classified or displayed will, in turn, help them learn how to select, sort, classify, code, synthesize and analyse information and, finally, how to communicate it. Tasks involving these skills will teach school students that classification and recording of data can be based on clear and stated criteria, and that the methods will be influenced by the purpose for which it will be used, such as to show relationships between fossils and evolution of life on Earth.

The "Journey in time and space" is an interactive educational multimedia application for students of compulsory education which supports scientific/geosciences literacy. Observations and data gathered by the "Journey in Time and Space" can lead to further questions for investigation. In some instances, these questions may be answered through further examination of the "real" objects and information available at the museum of geology and palaeontology of University of Athens. Alternatively, some questions may be answered through experimental processes carried out at school.

This multimedia production is encouraging as a learning medium for geosciences. Through describing such activities and analyzing design processes, we hope to provide inspiration to other researchers to "open" scientific collections to school students and general public, as well as to develop computer-supported collaborative learning environments in order to support geosciences literacy.

5. References

Bybee, R., 1997. Toward an understanding of scientific literacy. In Graber, W., & Bolte, C., (eds.), *Scientific literacy*, 37-68, Kiel, Germany, Institute for Science Education.

ESLI, 2009. *Earth Sciences literacy principles. The big ideas and supporting concepts of Earth Sciences*. National Science Foundation. Available online at: http://www. earthscienceliteracy.org/.

Fermeli, G., & Dermitzakis, M., 2008. The digitized collections of the Museums of Geology and Palaeontology educational tools for school education. *33rd International Geological Congress*, Oslo-Norway, 6-14 August, Vol. Abstracts, 1p.

Fermeli, G., & Marcopoulou-Diacantoni, An., 2004. Geosciences in the curriculum and text books of secondary education. Bulletin of the Geological Society of Greece vol. XXXVI, *Proceedings of the 10th International Congress*, Thessaloniki, 639-648.

Griffin, J., 1998. Learning science through practical experiences in museums, *International Journal of Science Education*, 20(6), 655-663.

Henriksen, E., & Frøyland, M., 2000. The contribution of museums to scientific literacy: views from audience and museum professionals, *Public Understanding of Science*, 9(4), 393-415.

Hurd, P. DeH. (1958). Science literacy: Its meaning for American schools. *Educational Leadership,* 16, 13-16, 52.

Laugksch, R. C. (2000). Science literacy: a conceptual overview. *Science Education*, 84(1), 71-94.

MacDonald, G., & Alsford, St., (1997). Conclusion: Toward the Meta-Museum. In Jones-Garmil, K., (ed.) *The Wired Museum - Emerging Technology and Changing Paradigms. A Review*. 267-277, Washington, D.C, American Association of Museums.

Millar, R., & Osborne, J., (eds.) 1998. *Beyond 2000: Science education for the future - The report of a seminar series funded by the Nuffield Foundation*, London, London King's College School of Education, 36pp.

Ministry of national education and religious affairs (YPEPTH), 2003a. *Curriculum for compulsory education*, Athens, Governmental newspaper, 304(B-13/3/03).

Ministry of national education and religious affairs (YPEPTH), 2003b. *Cross Curriculum framework for Geology-Geography*, Athens, Governmental newspaper 1196(B-26/8/03).

National Research Council, 1996. *National science education standards*. Washington, National Academy Press.

National Science Board, 2004. *Science and Engineering indicators 2004*. National Science Foundation. Available online at: http://www.nsf.gov/statistics/seind04/front/letter.htm.

OECD, 2003. The PISA 2003 *Assessment Framework -Mathematics, Reading, Science and Problem Solving Knowledge and Skills*. Paris, OECD, 200pp.

Trend, R., 2000. Conceptions of geological time among primary teacher trainees, with reference to their engagement with geosciences, history, and science, *International Journal of Science Education*, 22(5), 539-555.

UNESCO, 1993. *International forum of Scientific and Technological literacy for all, Final Report*, Paris, UNESCO.